ADVANCED MOTION COMPENSATION FOR AIRBORNE PLATFORMS: APPLICATION TO UAVSAR

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Topography and Azimuth-Dependent Motion Compensation

Motion Compensation Challenges for an Airborne Platform

Flight track is more difficult to repeat in an aircraft:

- Requires knowledge of aircraft motion and position to ~few cm level. (SOLUTION: combine INU and differential DGPS measurement for increased position and orientation accuracy)
- Large repeat track baselines lead to decorrelation. (SOLUTION: precision control of flight track to ±5 meters)
- Residual motion smaller than the detected motion must be estimated to achieve sub-centimeter deformation accuracy. (SOLUTION: advanced processing algorithms to estimate residuals from image offsets between repeat tracks)

Aircraft attitude angles depends upon variable flight conditions:

- Variable wind conditions can cause the aircraft yaw angle to change on a timescale smaller than the synthetic aperture formation time during a flight line. (SOLUTION: adaptively steer antenna during a flight line to compensate yaw variation)
- Both yaw and pitch can be different between repeat tracks because of wind, fuel load, velocity, and initial conditions. (SOLUTION: Adaptive steering to planned flight track, plus process data to the doppler angle that maximizes spectral overlap between the data from the different tracks)

Additional Challenges for High Precision Repeat Track Interferometry

Traditional mocomp ignore the effects of surface topography and finite beam width:

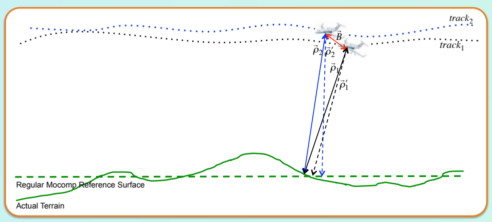
$$\Delta\rho = \frac{\lambda\Delta\phi}{4\pi} = \Delta\rho_{surface} + \overbrace{\Delta\rho_{motion}}^{\text{Remove in motion compensation}}$$

$$\Delta\rho_{motion} \approx \vec{B}\bullet\frac{\vec{\rho}}{\rho}$$

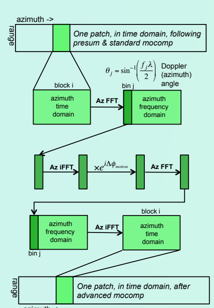
$$\hat{l} \equiv \frac{\vec{\rho}}{\rho}$$

Terrain and attitude angle differences both cause an error in track alignment, and affect both B and Î.

Errors in the baseline, B, or the look direction, Î, lead to errors in the interferometric phase and hence to the derived deformation.



- The advanced mocomp algorithm is implemented after standard motion compensation and before azimuth compression.
- The data from a single patch is separated into blocks to account for fast attitude changes.
- The data is Fourier transformed in the azimuth direction to obtain the doppler angle-dependence. The azimuth angle is determined from the frequency of each bin in the inverse FFT azimuth frequency spectrum.
- The terrain height is determined from the intersection of the doppler cone, the surface ellipsoid and the slant range sphere, iterating to match the DEM height at the intersection point.
- The interferometric phase correction is calculated with the new look direction and baseline.

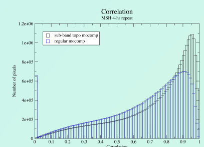


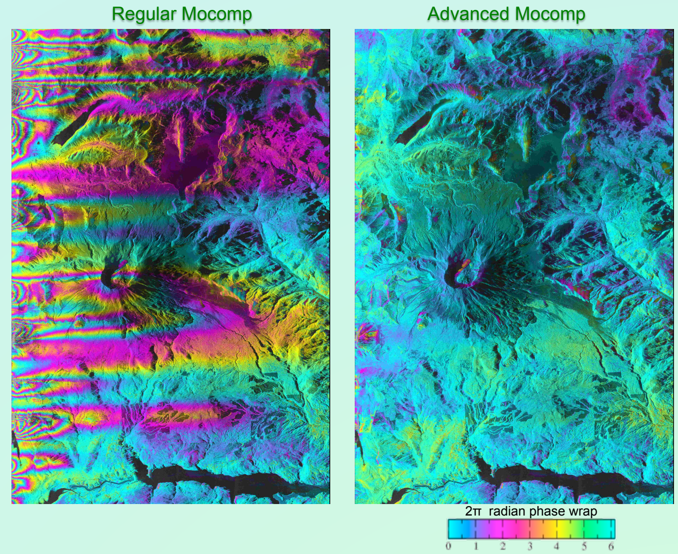
Process Flow

Effect on UAVSAR Repeat Track Interferometric Results

Repeat Track Interferograms

Mount Saint Helens
3/24/2008
4 hr repeat interval





Residual Motion Estimation

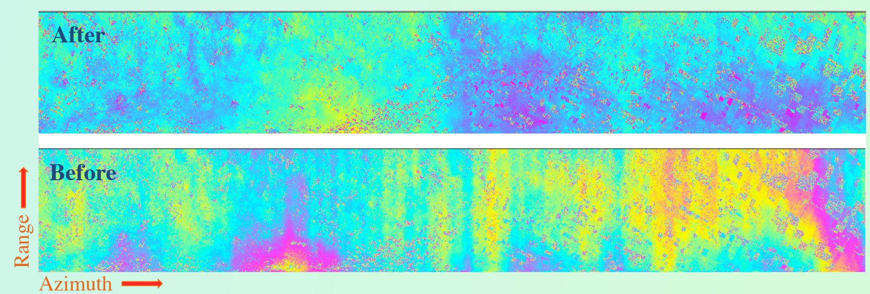
The unknown motion residuals that remain after processing with the advanced motion compensation algorithm are estimated from the measured offsets in range and azimuth between the images for the two tracks.

$$\Delta s \approx (\hat{v}\bullet\hat{s})\left(\frac{\sin\alpha_{steer}(\vec{B}\bullet\hat{l}) - (\vec{B}\bullet\hat{n}_{Doppler}) + \rho\hat{l}_c\frac{\partial B_c}{\partial s} + \rho\hat{l}_h\frac{\partial B_h}{\partial s}}{\hat{v}\bullet\hat{n}_{Doppler} - \sin\alpha_{steer}(\hat{v}\bullet\hat{l})}\right)$$

$s =$ along track (azimuth)

$c =$ across track

$h =$ vertical



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